

MODIS QUARTERLY REPORT: JAN/01/97 --- MAR/31/97

Radiative Transfer Based Synergistic MODIS/MISR Algorithm for the Estimation of Global LAI \& FPAR

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The objective of our effort is to develop a radiative transfer based synergistic algorithm for the estimation of global leaf area index (LAI) and fraction of photosynthetic active radiation absorbed by vegetation (FPAR) from atmospherically corrected MODIS and MISR spectral reflectance data. The algorithm consists of a main procedure (Look-up-table or LUT) and a back-up procedure (using Vegetation Indices or VI). A comprehensive three-dimensional radiative transfer (RT) model for vegetated surfaces is utilized by both the procedures to estimate LAI and FPAR fields. The algorithm requires a land cover classification that is compatible with the radiative transfer model. The following is a brief description of our activities during the first quarter of 1997 (January through March).

The backup algorithm has been fully derived and the biome-dependent vegetation index vs LAI and FPAR relations have been established. This was done with the improved radiative transfer model, especially in the case of forest canopies. The derived relations have been coded into the algorithm by the University of Montana group (PI: Dr. Running).

With the backup algorithm established, we are now developing the main MODIS/MISR synergistic algorithm. This algorithm exploits the spectral information from the MODIS instrument and the angular information from the MISR instrument to derive accurate estimates of LAI and FPAR. The following is a description of the details of work performed during this quarter on the main algorithm.

The main algorithm for estimating LAI and FPAR from MODIS/MISR includes the following components.

(a) RT Model: A family of RT models which can predict the reflection functions of various types of vegetation covers (BIOMES). The algorithm is designed to be independent of the RT model(s) used to build the look-up-table.

(b) Look-up-Table: This is an array containing some variables estimated

from RT models; the variables are components descriptive of the various forms of energy conservation law. They are determined from general properties of radiative transfer, independently of the RT model. At the present time, we use our RT models to evaluate these components.

(c) Mathematical Tools: These are used to derive simple relationships between spectral and angular composition of radiation measured by MODIS/MISR and LAI/FPAR using a Look-up-Table.

(d) Retrieval Tools: These are used to retrieve LAI and FPAR from measured data and relationships derived by the mathematical tools.

Details of the Algorithm

The distribution of solar radiation in vegetation canopies is determined by (a) the incident radiation field (direct, diffuse, sun position), (b) canopy architecture, (c) leaf spectral properties, and (d) soil spectral properties. The BRDF can be expressed in terms of the soil reflection coefficient, and the solution of the following two problems:

(a) The upward and downward energy flux at the canopy bottom generated by isotropic diffuse radiation incident on the canopy (pi problem).

(b) The downward energy flux at the canopy bottom in the case of standard radiative transfer problem, i.e., radiative transfer problem with vacuum boundary conditions and mono-directional incidence (standard problem).

The pi problem depends on leaf spectral properties and canopy structure only. The standard problem depends additionally on the sun-view geometry. Even in the ideal case, where, one can measure the BRDF exactly, the problem of estimating LAI and FPAR is ill-posed, in a mathematical sense. Therefore, additional information is required to reduce the uncertainty of estimation. The spectral variation of BRDF (which is the strength of MODIS) is taken here as this additional information.

Our investigations of radiation transfer with respect to variations in leaf spectral properties, carried out during this quarter, allow us to formulate the following principle for the pi and standard problems:

"variations in the radiative field caused by variations in leaf spectral properties are proportional to the positive eigen vector of a special form of the radiative transfer equation. The factor of proportionality is the unique positive eigen value of this equation which depends on the leaf spectral properties and canopy structure."

The evaluation and detailed description of the eigen value is key to the synergistic algorithm because,

- (a) the eigen value depends on leaf spectral properties and canopy structure only (while the eigen vector depends on the sun-view geometry, canopy architecture, leaf spectral properties and the eigen value);
- (b) the eigen value can be measured from MODIS and MISR as the ratio of reflected radiation at different spectral bands; and
- (c) it allows us to reduce the size of the Look-up-Table significantly, because we can do all the necessary calculations at one fixed wavelength only.

We derived an explicit form of the eigen value for a canopy with uniform leaf normal distribution, evaluated certain constants needed to specify this value, performed a detailed comparison of this technique with calculations using RT models. Thus, we can express the spectral Directional Hemispherical Reflectance (DHR) as a product of the DHR for a fixed wavelength and the eigen value. This allows us to use BRDF measurements at many different wavebands, without increasing the size of Look-up-Table, and also, to extend the applicability of any BRDF model (usually designed for visible region of solar spectrum) to account for the spectral variation of canopy reflectance. Some investigation was also done to relate FPAR with the eigen value, and this will be continued in the next quarter.

As a first step, we will use the least squares method to retrieve LAI and FPAR by minimizing the difference between measured and simulated spectral DHR, the latter obtained from our representation of reflected radiation via the soil reflection coefficient, the π and standard problems, at fixed wavelength and eigen value of the radiative transfer equation. Thus, for each biome or landcover type, we need to store in a Look-up-Table the following information:

- (a) canopy transmittance and reflection for the π and standard problems at one fixed wavelength, as a function of LAI and sun-view geometry;
- (b) leaf spectral reflectance and transmittance;
- (c) a mathematical function (recently derived) of LAI needed to specify eigen value and,
- (d) discrete view and sun angles.

The work performed in this quarter is significant because we were able to obtain some important results which allowed us to cut down the size of the look-up-table substantially, and to truly exploit the synergistic nature of MODIS and MISR measurements. During the next quarter, we will continue work on the algorithm, with the aim of making available a version 0 of the algorithm and to publish the details in peer-review journals.